



# High- $p_T$ $\pi^0, \eta$ , Identified and Inclusive Charged Hadron Spectra from PHENIX

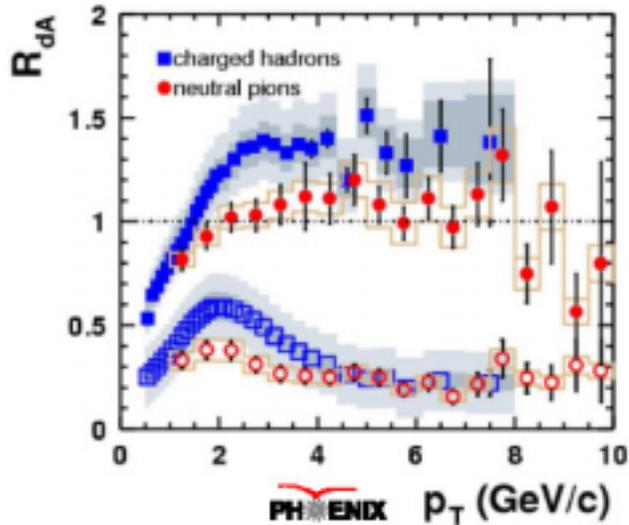
Maya SHIMOMURA  
University of Tsukuba  
for the PHENIX Collaboration

# Physics motivation

What we have studied.

Comparison between Au+Au and d+Au collision with high energy.

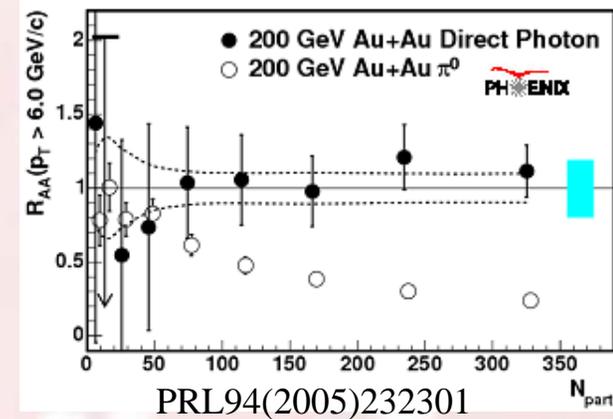
d+Au, Au+Au at  $\sqrt{s_{NN}} = 200$  GeV



\*No suppression in d+Au collision while Au+Au has factor 3 suppression at high  $p_T$ .

<Possible explanation>

- Cronin effect in nuclear. (Initial)
- Gluon interaction in hot dense matter. (final)



\*PRL 91 072303 (2003)

\*Direct photon is not suppressed.

The suppression at high  $p_T$  is due to the final state interaction.

<Question>

Dependence on the System size ?

Dependence on the particles species ?

# PHENIX Detectors

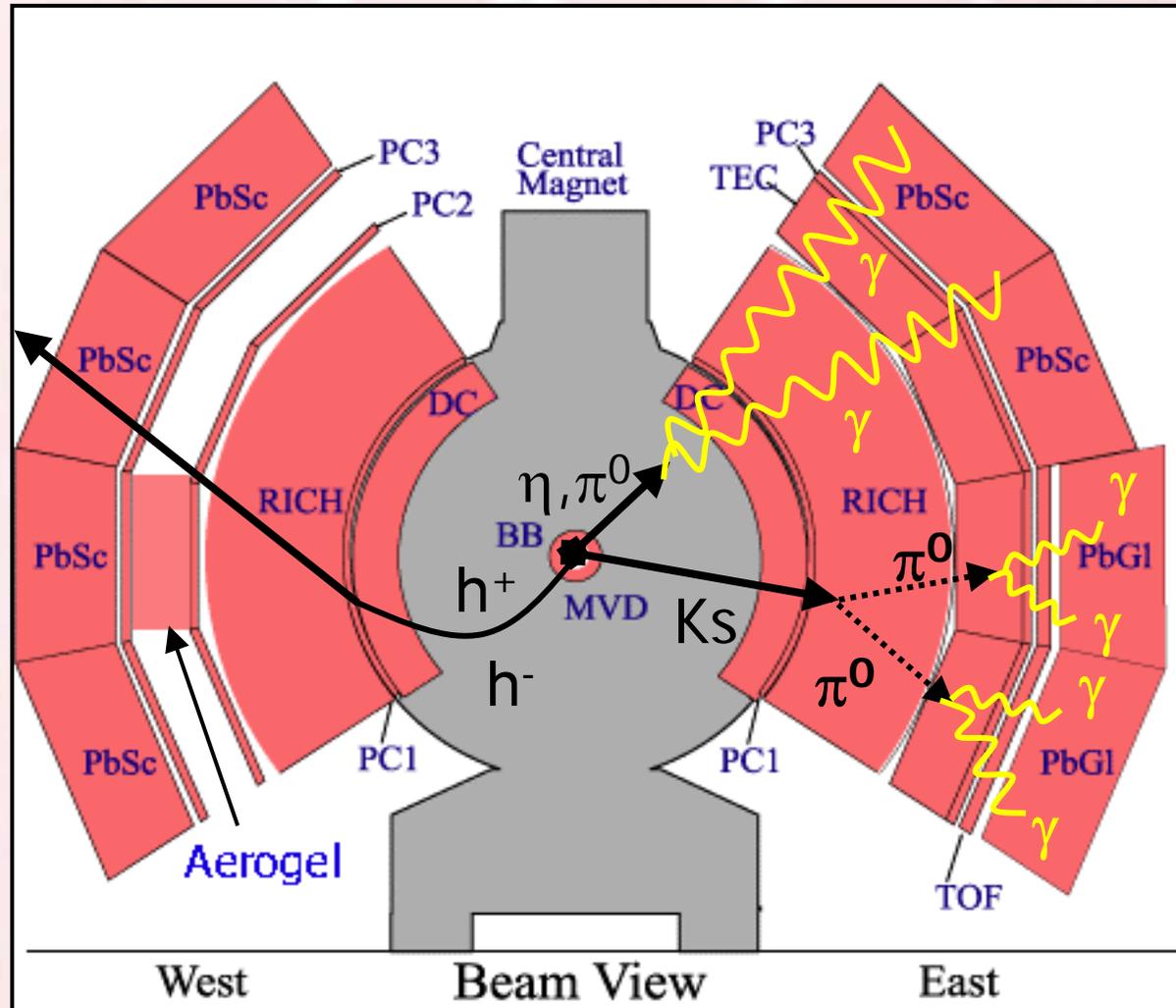
EMCAL --- measure energy deposit of electron and gamma

DC --- obtain momentum of charged particles

PC --- measure hit position of charged particles

Tracking and Matching (DC, PC)  
→ charged hadron

EMCAL (PbSc + PbGl)  
→  $\eta, \pi^0, K_s$



# Spectra

# Spectra in different systems

$$\sqrt{s_{NN}} = 200\text{GeV}$$

<Au+ Au @ 200GeV>

- $\pi^0$  spectra
- $\eta$  spectra
- charged hadron spectra

<Cu + Cu @ 200GeV>

- $\pi^0$  spectra
- charged hadron spectra

<d+ Au>

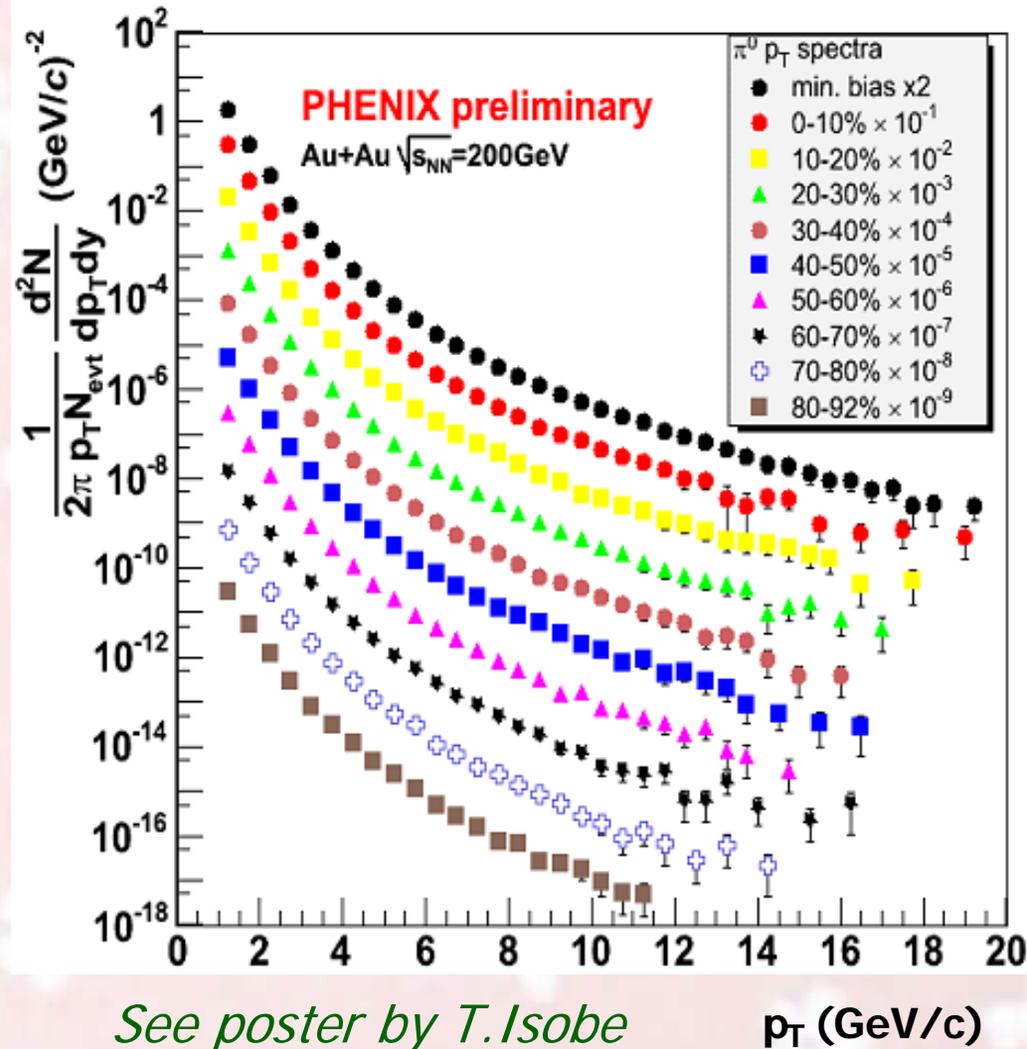
- Ks spectra
- $\eta$  spectra

<p+p>

- Ks spectra
- $\eta$  spectra

$\pi^0$

Au+ Au

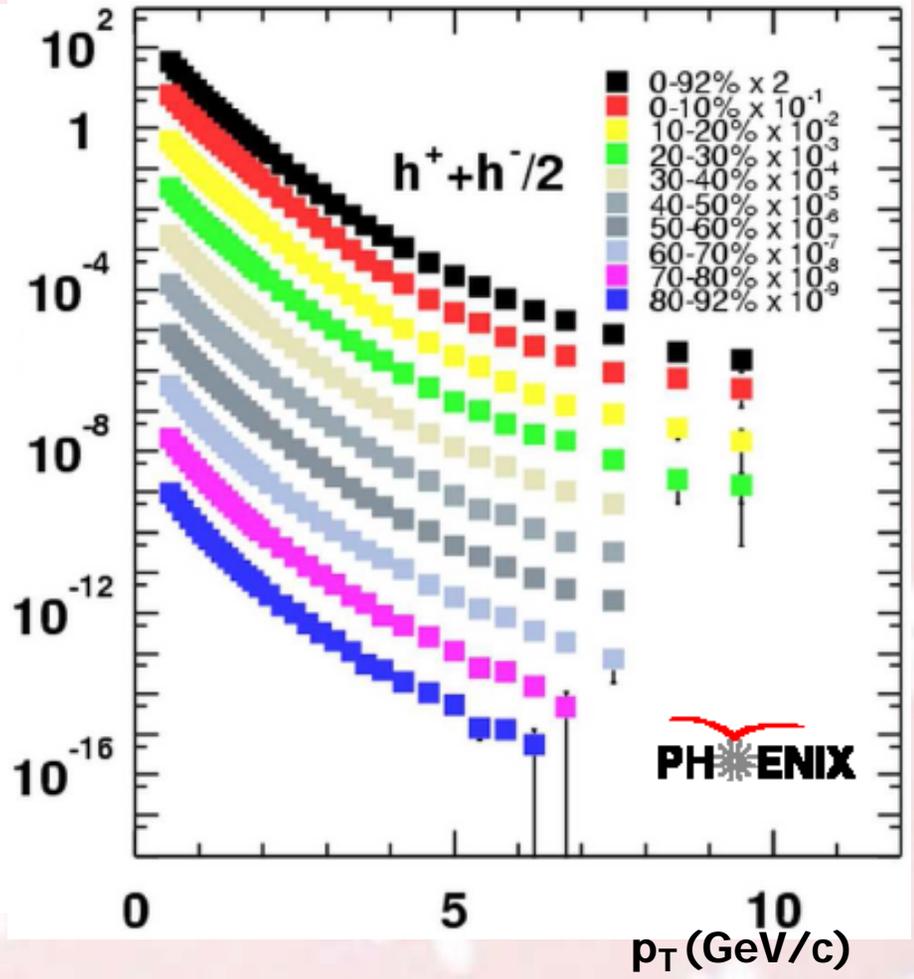
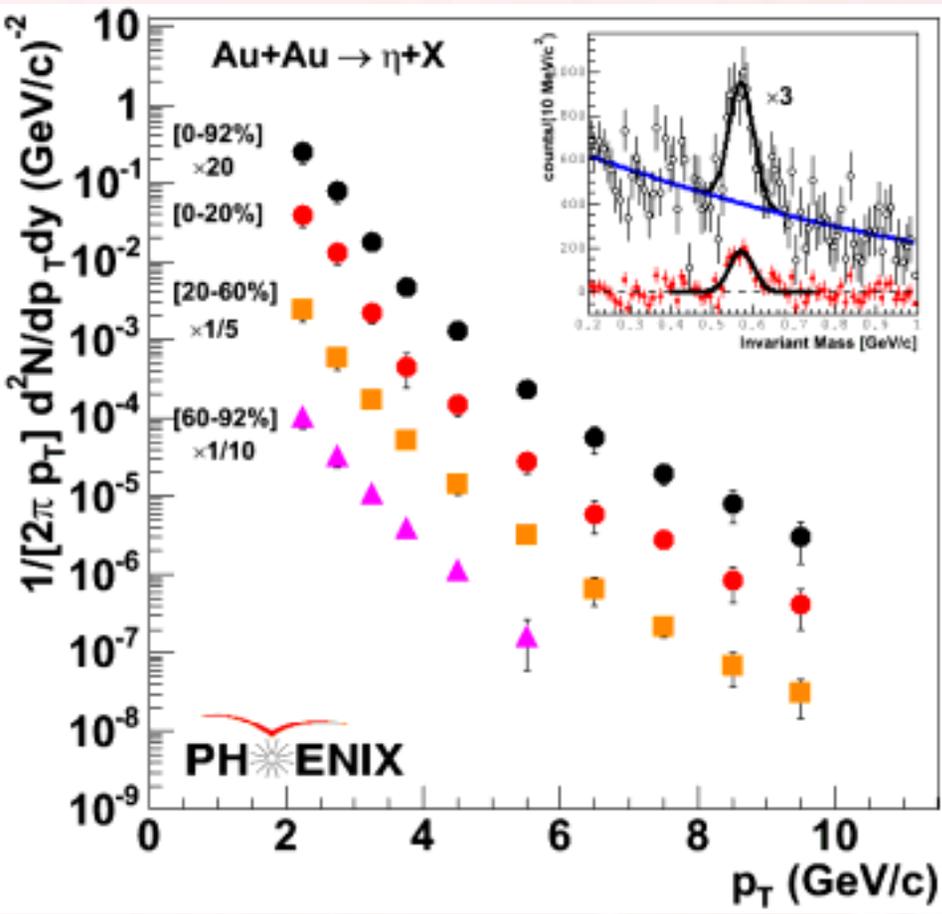


# Spectra in Au+Au

$$\sqrt{s_{NN}} = 200\text{GeV}$$

$\eta$

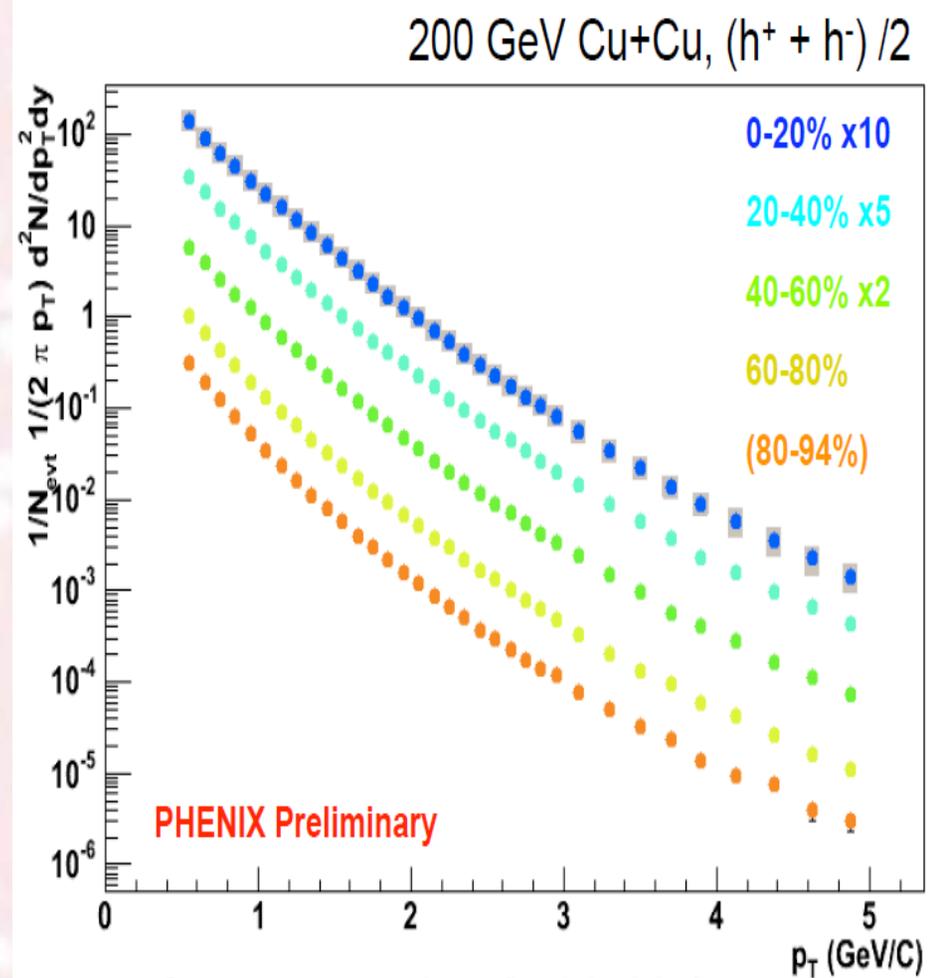
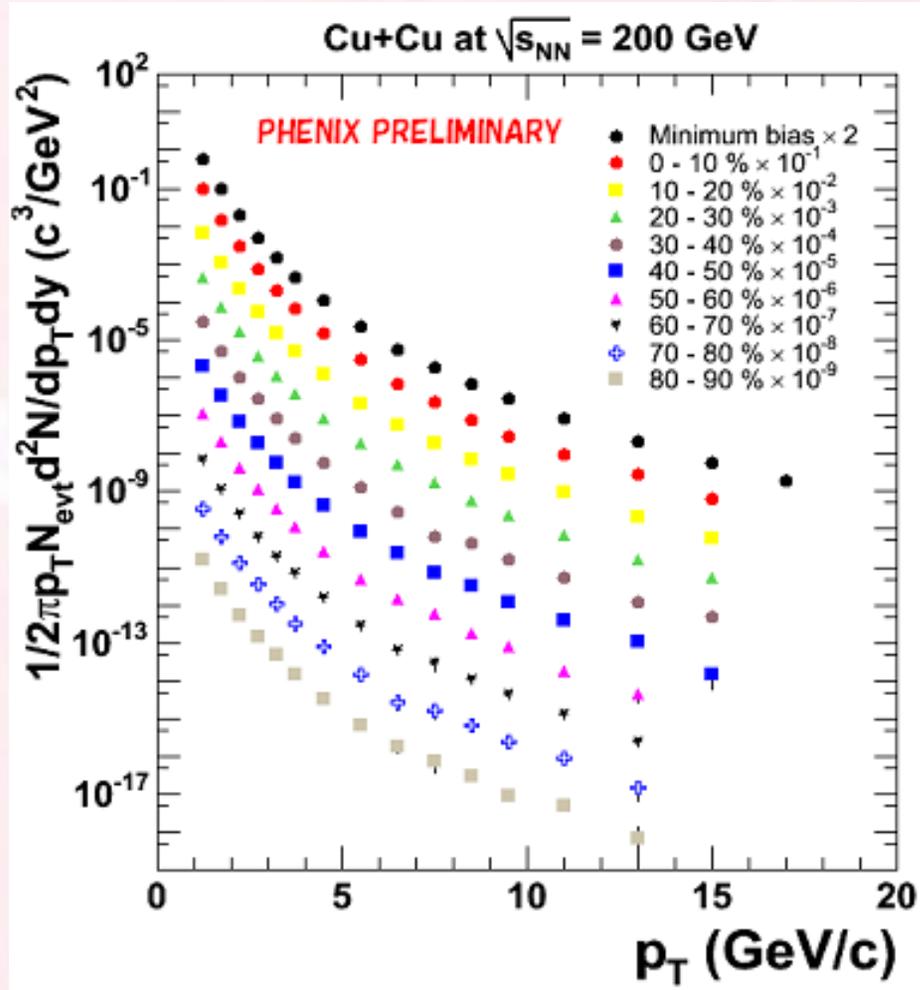
Charged Hadron



# Spectra in Cu+Cu $\sqrt{s_{NN}} = 200\text{GeV}$

$\pi^0$

Charged Hadron

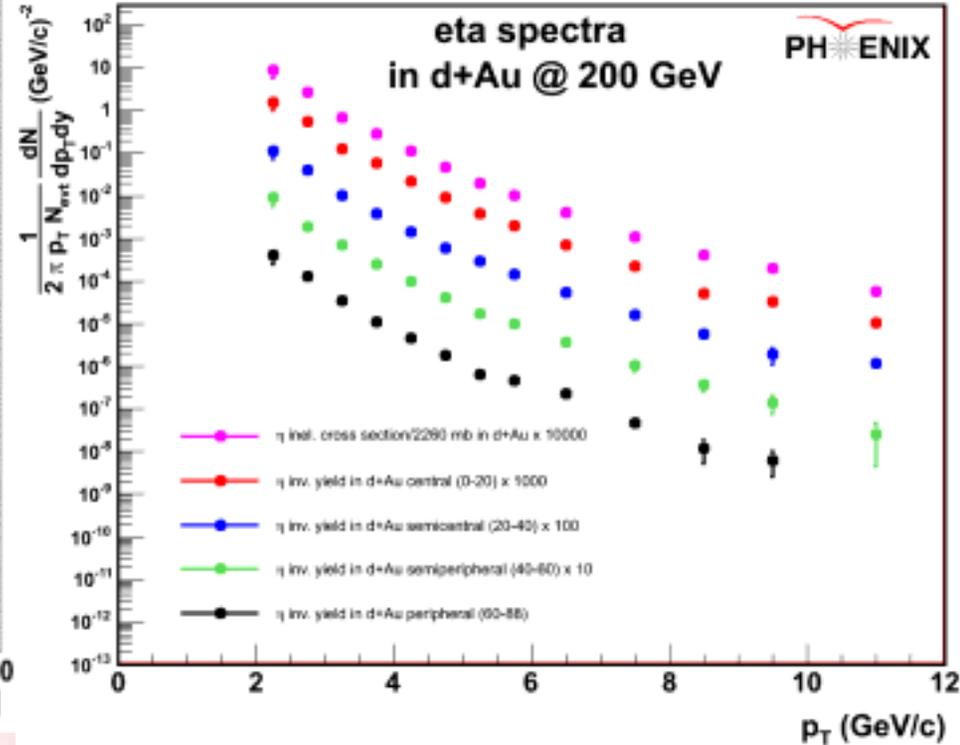
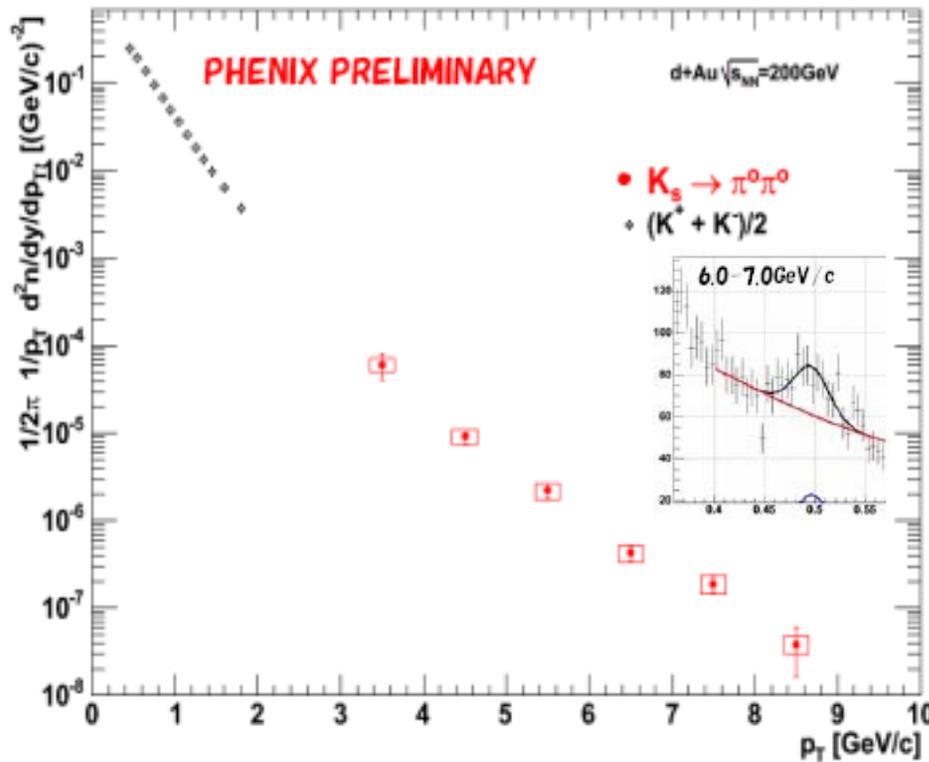


See poster by C. M. Vale

# Spectra in d + Au $\sqrt{s_{NN}} = 200\text{GeV}$

$K_S^0$

$\eta$

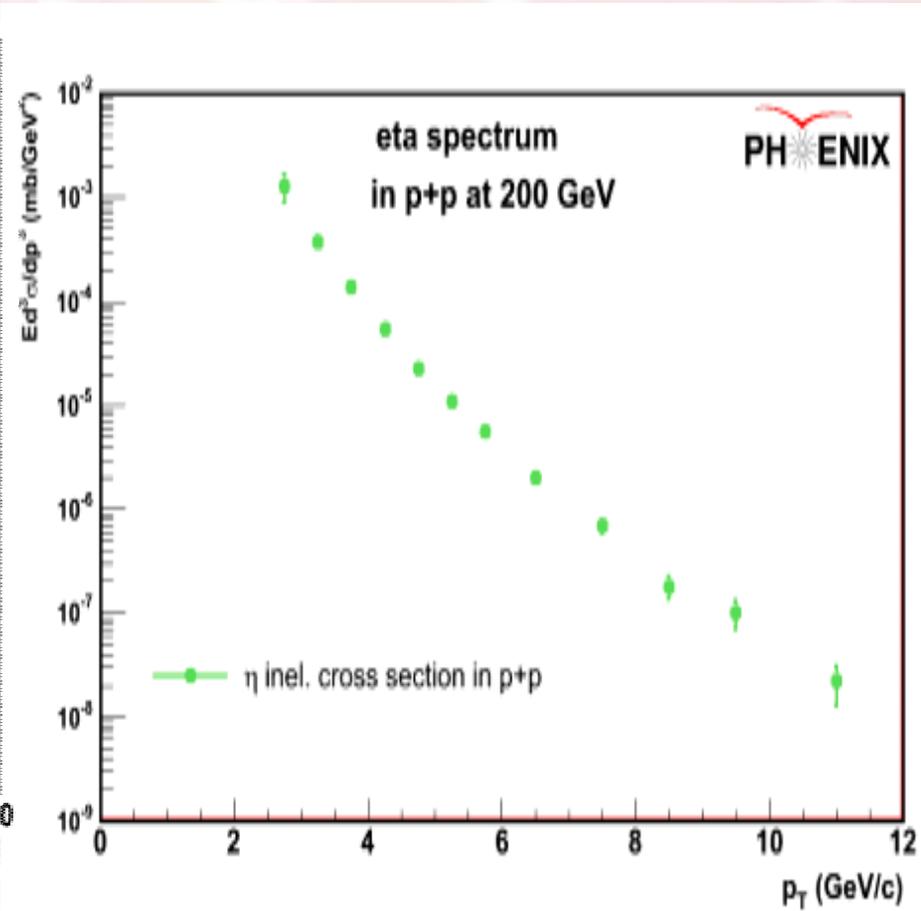
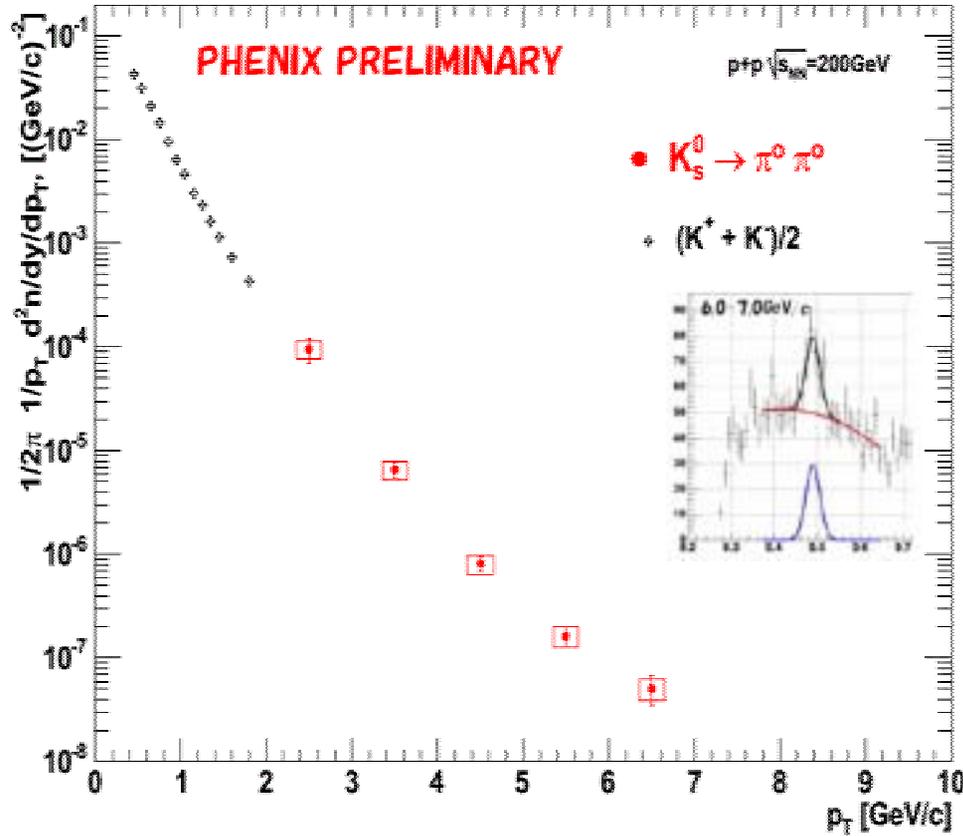


See talk and poster by V.G. Ryabov

# Spectra in p + p $\sqrt{s_{NN}} = 200\text{GeV}$

$K_S^0$

$\eta$



# $R_{AA}$

Comparison to p+p collision data

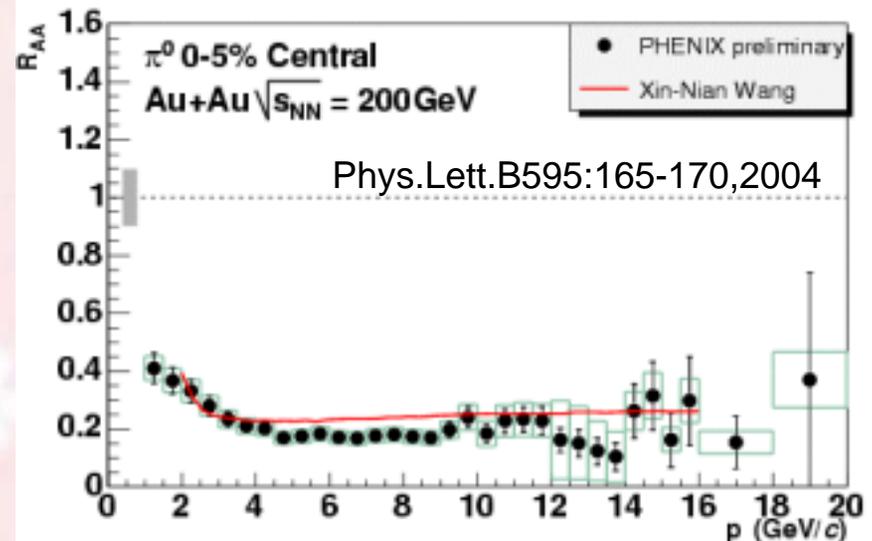
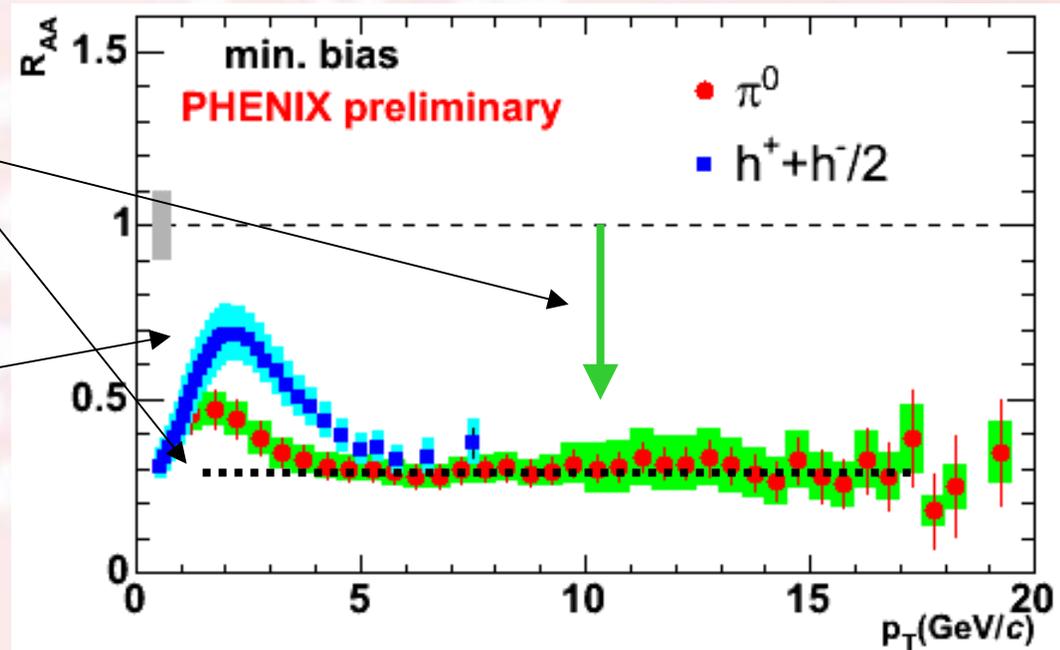
# $R_{AA}$ for $\pi^0$ and **Charged Hadron** <Minimum bias>

<Au + Au>

- factor 3 suppression.
- Constant out to 20 GeV/c.
- Clear difference between  $\pi^0$  and charged hadron for  $p_T < 5 \text{ GeV/c}$ .

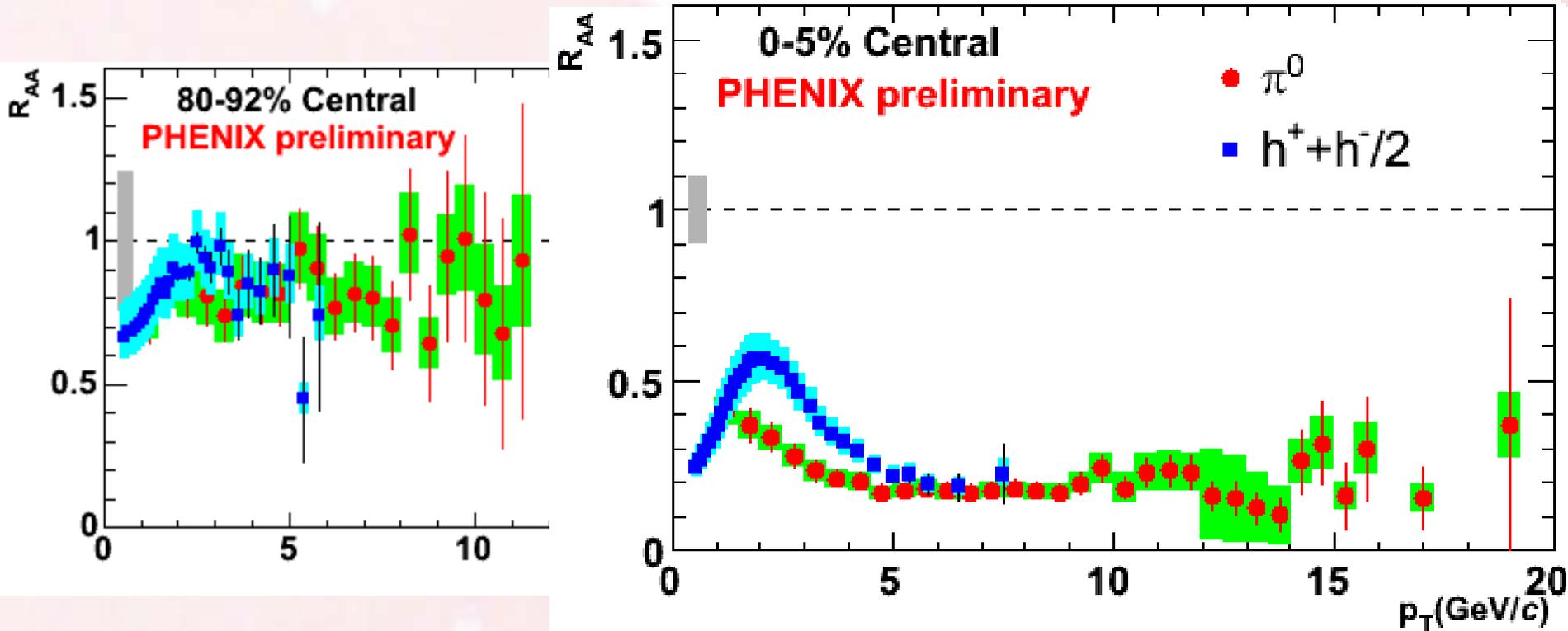
(Ref: talk by D.L.Winter for reaction plane dependence)

The data is consistent with energy loss models. (XN-Wang, GLV).



# Centrality evolution of $R_{AA}$

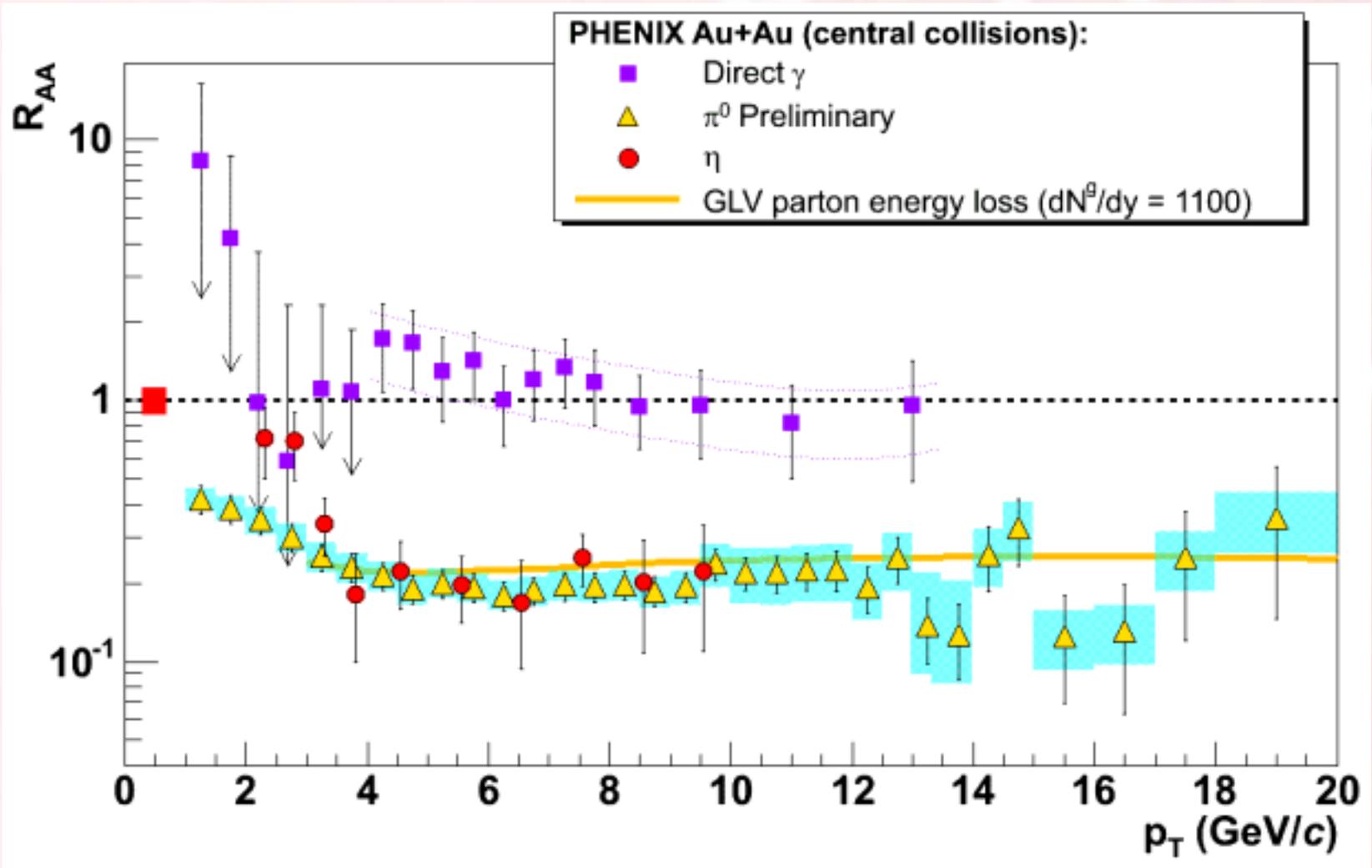
<Peripheral to Central Au+Au Collision>



- Stronger Suppression for more central collision.
- $\pi^0$   $R_{AA}$  is flat for all centrality for  $p_T > 5$  GeV/c.
- Difference between  $\pi^0$  and charged increases for  $p_T < 5$  GeV/c.

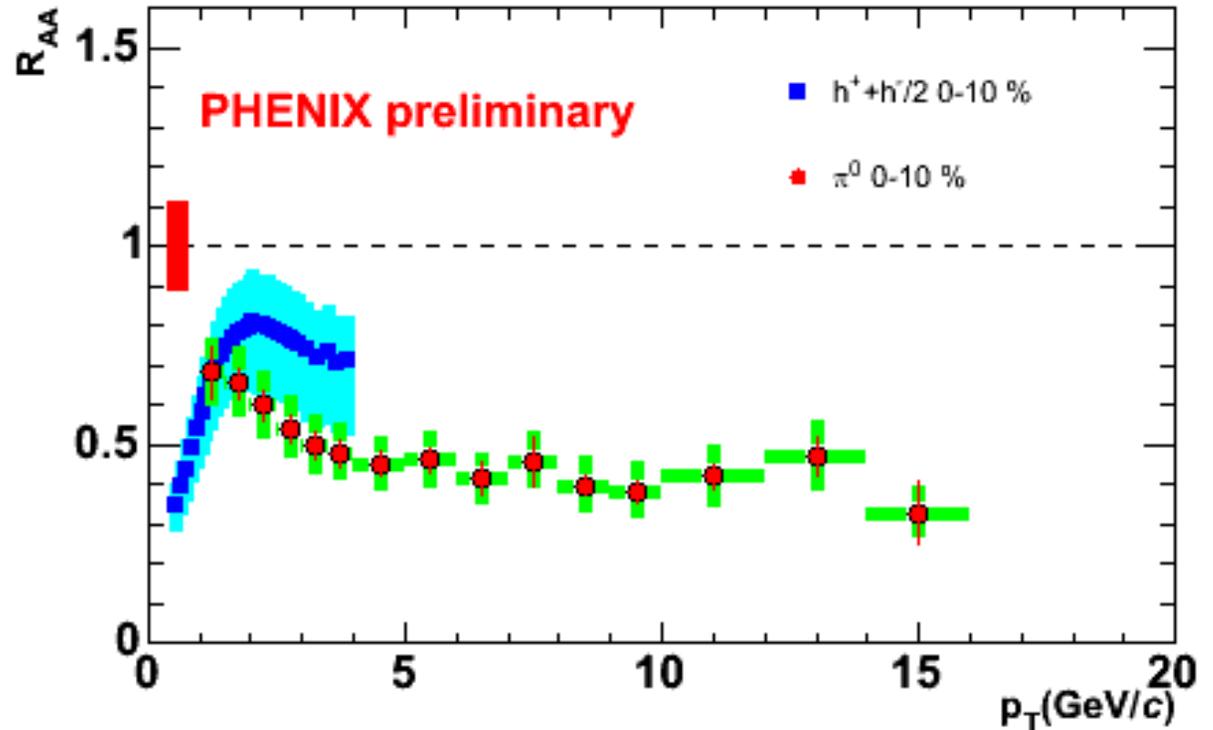
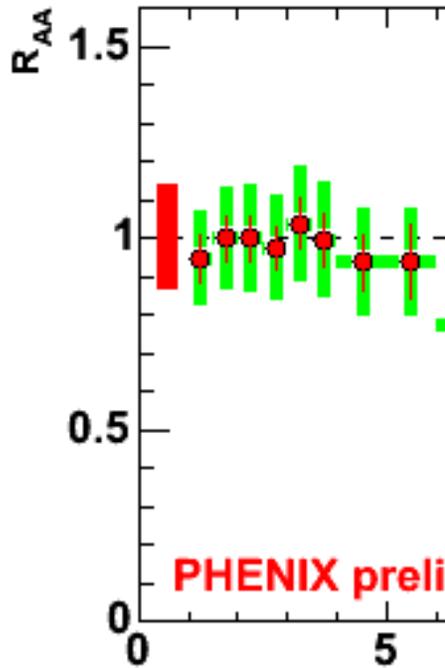
# RAA of $\eta$

In Au + Au



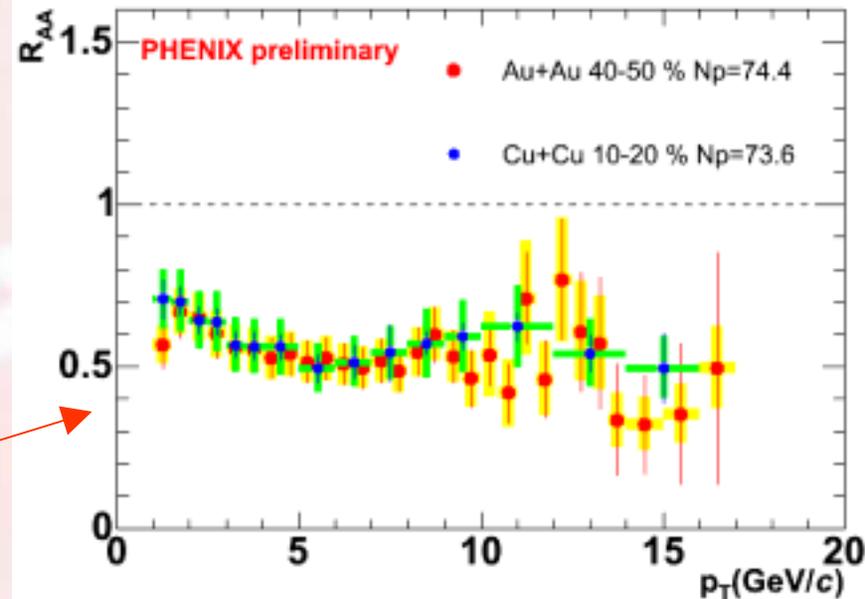
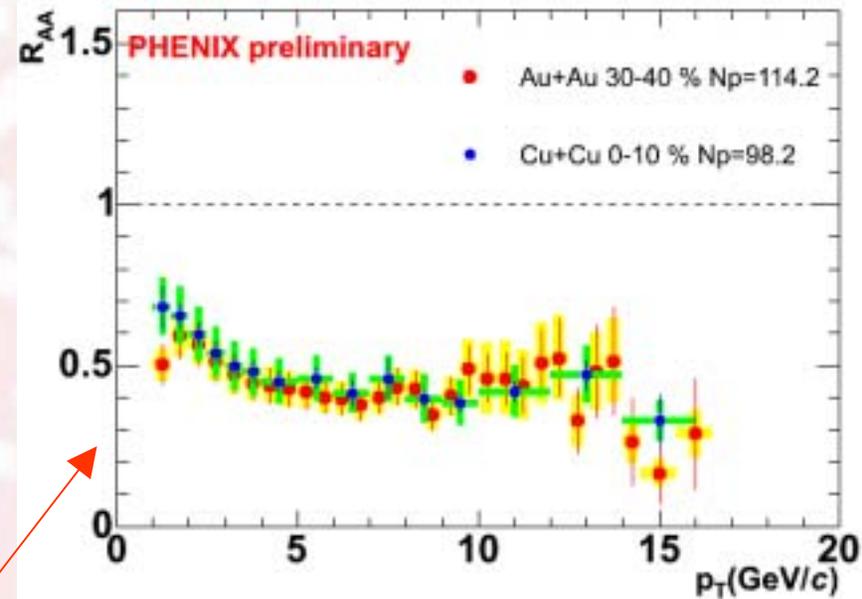
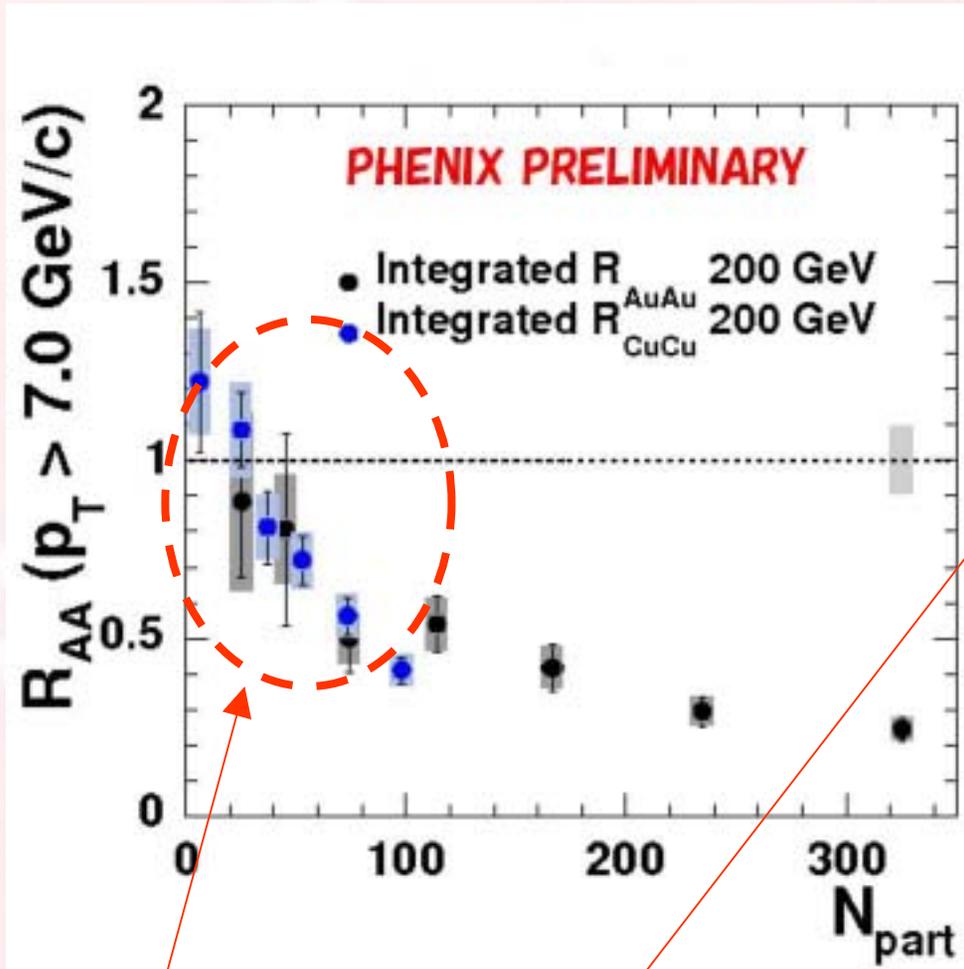
Suppression is similar to  $\pi^0$

# $\pi^0$ and Charged Hadron $R_{AA}$ in Cu + Cu



- $R_{AA}$  is 1 within error for peripheral collision.
- $R_{AA} \sim 0.5$  for most central collision.
- Charged Hadron  $R_{AA}$  is higher in more central collision.

# Comparison between Au+Au and Cu+Cu



Both behave same at mid central.

# High $pT$ Particle Ratio

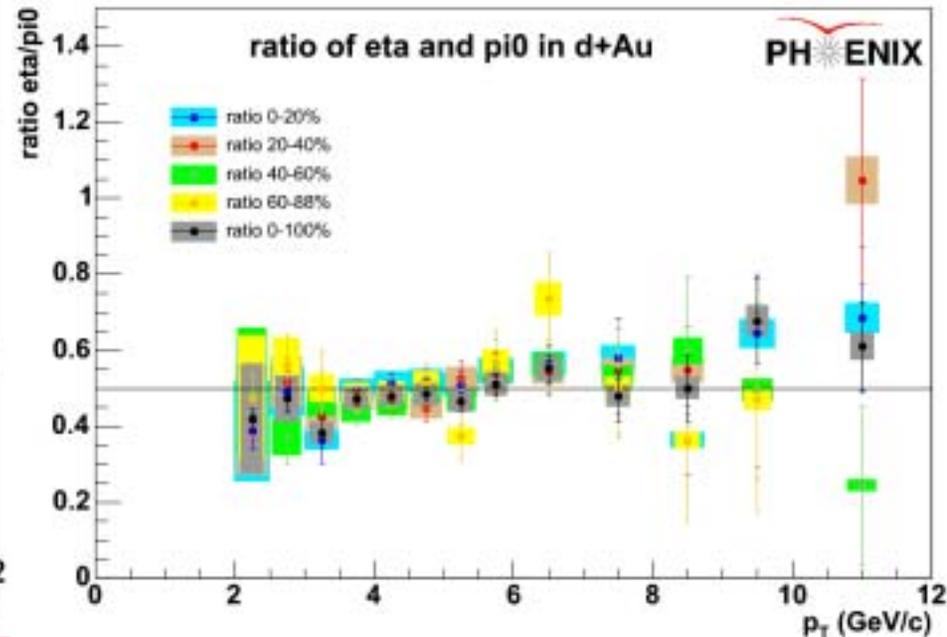
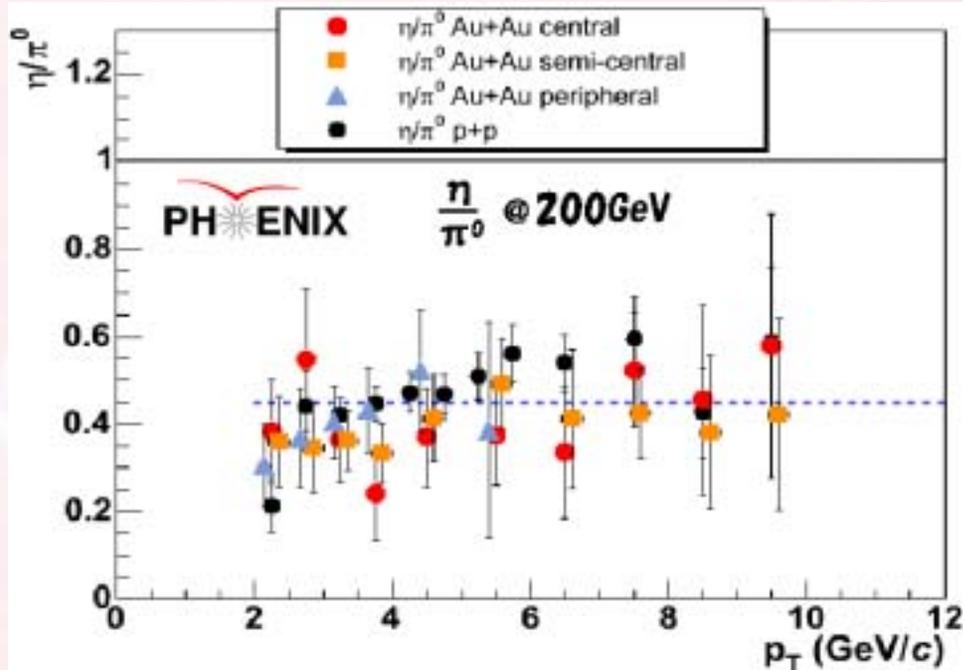
$$\eta / \pi^0$$

$$\sqrt{s_{NN}} = 200\text{GeV}$$

p+p

Au+Au

d+Au



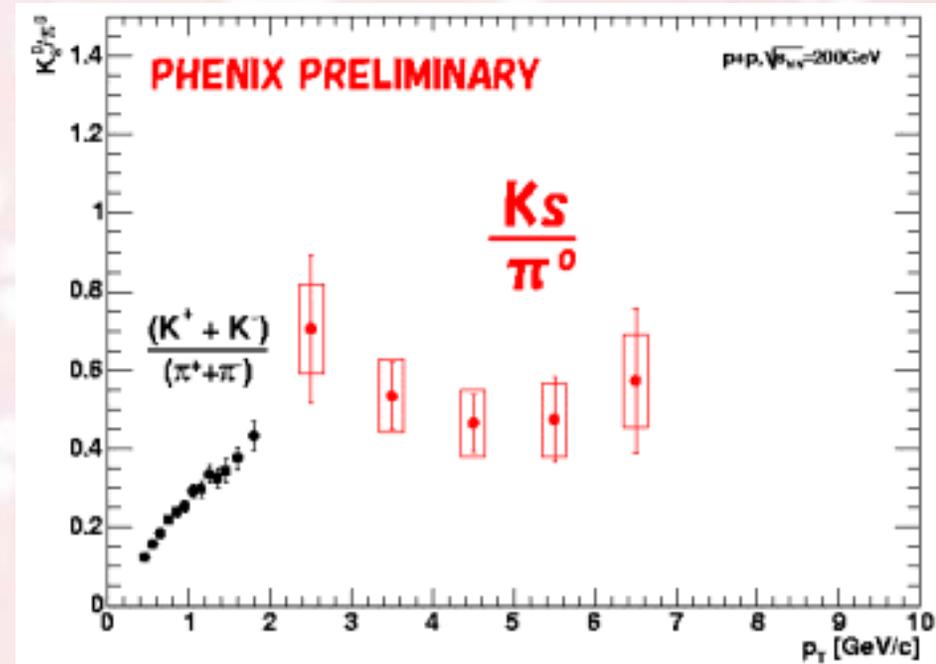
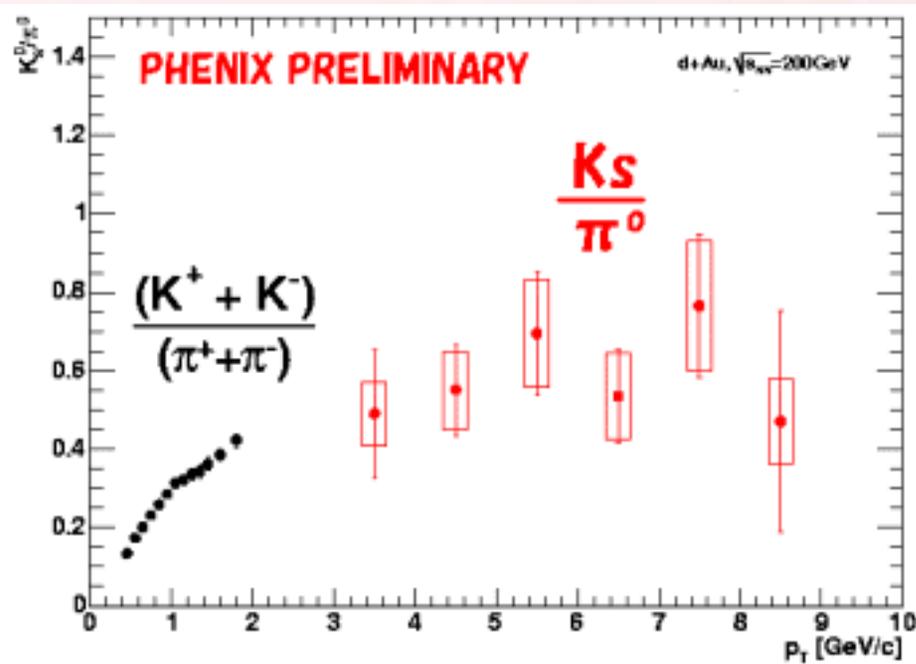
$\eta / \pi^0 \sim 0.4 - 0.5$ . in all systems and for all centralities.

$$K_s / \pi^0$$

d+Au

$$\sqrt{s_{NN}} = 200\text{GeV}$$

p+p



$K_s/\pi^0$  ratio becomes flat at high  $p_T$ .

# Summary

- High  $p_T$   $\pi^0$  suppression is flat out to 20 GeV/c in Au + Au.
  - Consistent with Energy loss models.
- $\eta$  has a similar suppression pattern as  $\pi^0$ .
  - Suppression is flat as function of  $p_T$ .
- $\pi^0$  and charged hadron are also suppressed in central Cu+Cu collision.
  - RAA is  $\sim 0.5$  for  $\pi^0$
- RAA comparison between Au+Au and Cu+Cu
  - Suppression is similar for similar  $N_{part}$
- $\eta/\pi^0$  ratio =  $\sim 0.4 - 0.5$ ,
  - The ratio is independent of centralities and system size.
  - The ratio is similar to pp/dAu, consistent with Jet fragmentation.

感謝

Thanks To Many Effort



I am proud of our colleagues!



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Department of Public Information Cartographic Section

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**\*as of March 2005**

## Related talk and poster

### <Talk>

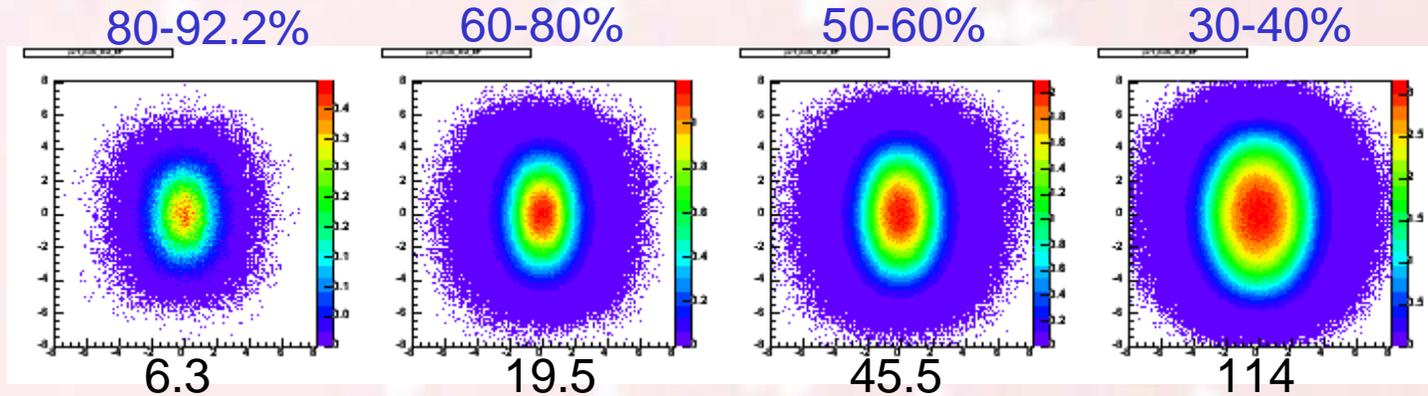
- 1a M.Konno "Systematic study of identified particle production in PHENIX"
- 3a D.L.Winter "PHENIX measurement of particle yields at high  $p_T$  with respect to reaction plane in Au+Au collision at  $\sqrt{s_{NN}} = 200\text{GeV}$ "
- 6b V.G.Ryabov "First measurement of the  $\omega$ -meson production at RHIC by PHENIX"

### <Poster>

- 32 C.M.Vale "Charged hadron transverse momentum spectra in Cu+Cu collisions from PHENIX"
- 74 T.Isobe "Measurement of neutral pions in  $\sqrt{s_{NN}} = 200\text{GeV}$  and  $62.4\text{GeV}$  Au+Au collisions at RHIC-PHENIX"
- 192 K.Miki "Measurement of inclusive photon and direct photon  $v_2$  in  $\sqrt{s_{NN}} = 200\text{GeV}$  Au-Au collision with the PHENIX experiment at RHIC"
- 200 M.L. Purschek "Measurement of eta  $p_T$  distribution in  $\sqrt{s_{NN}} = 200\text{GeV}$  Au-Au collision at RHIC-PHENIX"
- 203 Y.G. Riabov "Measurement of multiparticle hadron decays of light mesons at PHENIX"

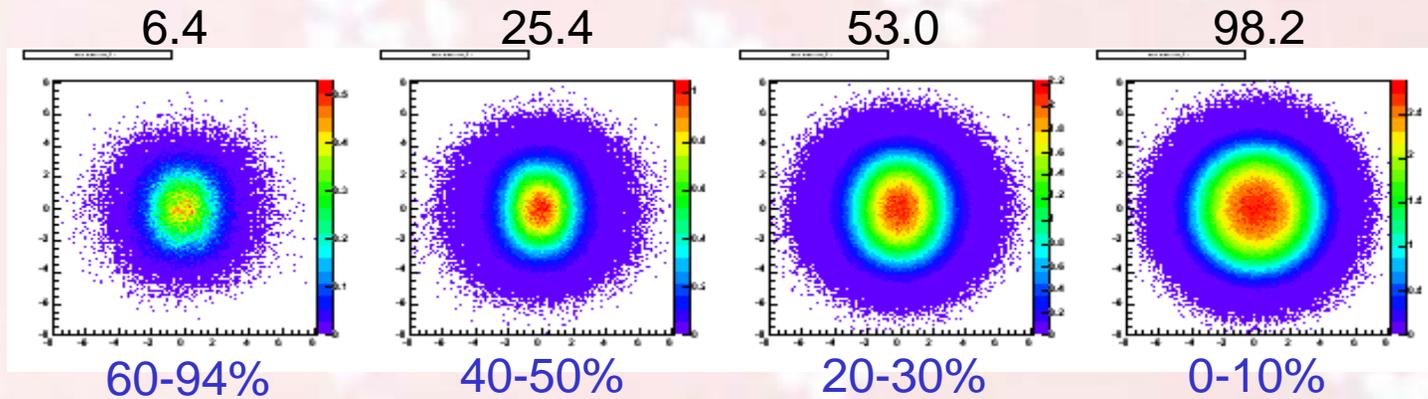
Back  
up  
slides

$$N_{\text{part}}(x,y)$$



Au+Au

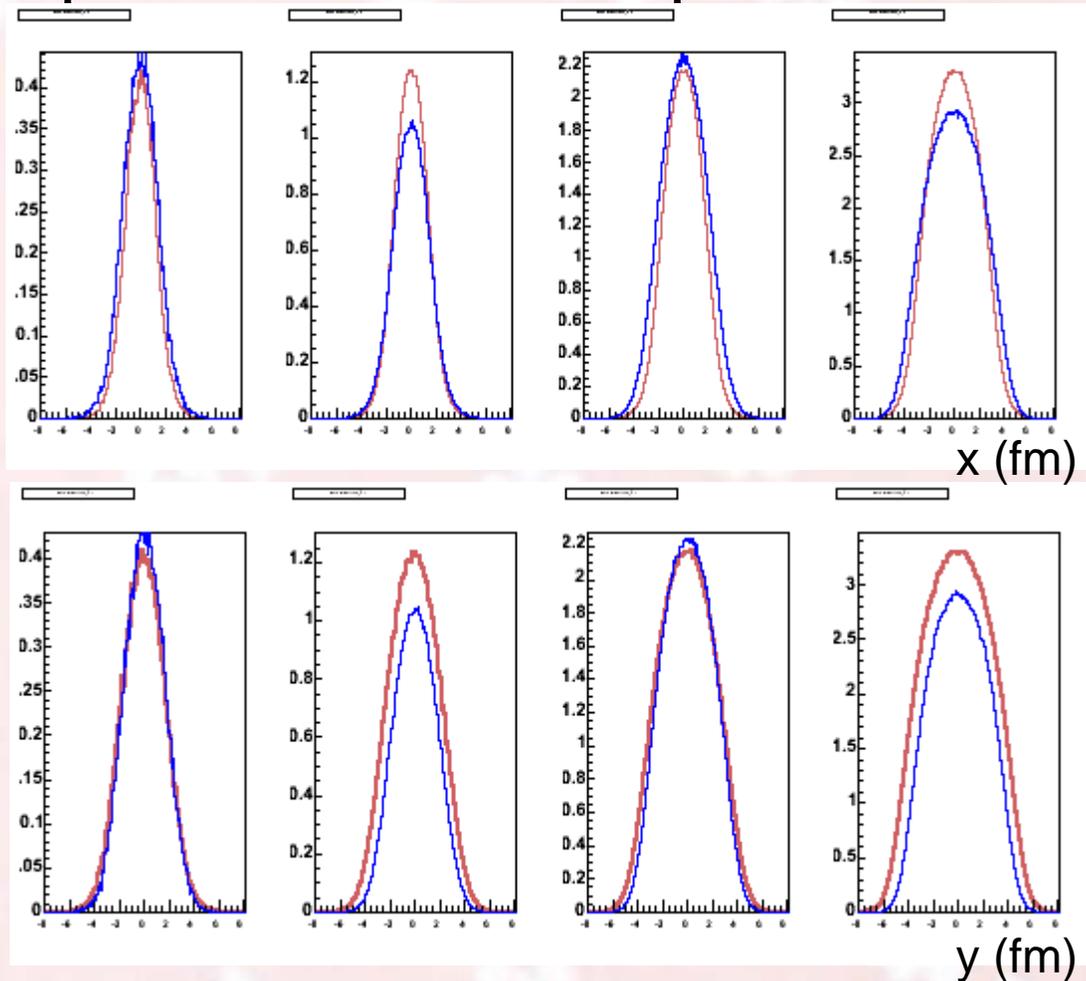
<Npart>



Cu+Cu

Distribution of  $N_{\text{part}}$  density versus  $x$  and  $y$  (in fermi) for similar  $\langle N_{\text{part}} \rangle$  in Au+Au, Cu+Cu  
 Ellipticity is very different –  $v_2$  should be quite different for same  $\langle N_{\text{part}} \rangle$

$$N_{\text{part}}(x, y=0), N_{\text{part}}(y, x=0)$$

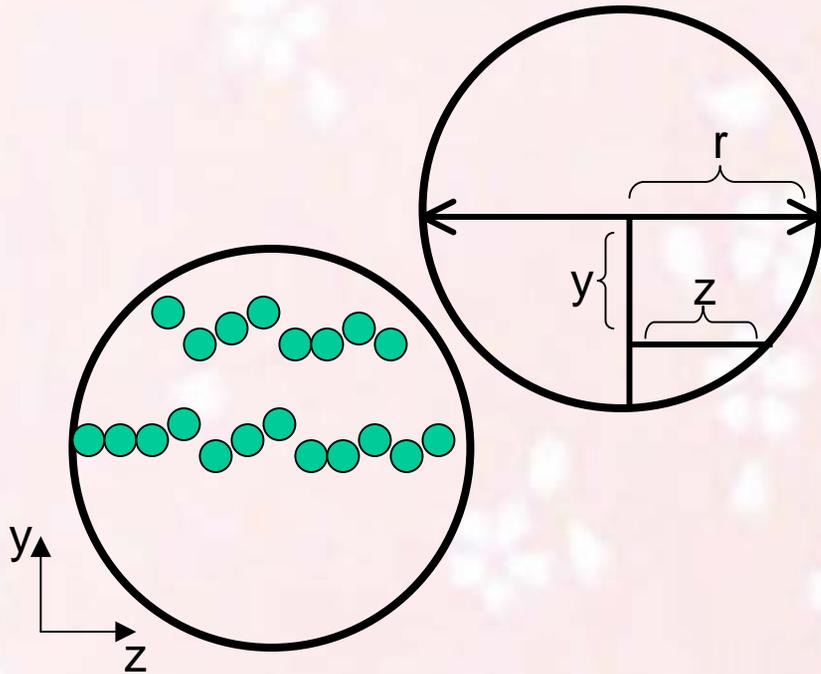


blue = Cu+Cu  
red = Au+Au

Projection of Npart density in x and y

Shows that Npart density in Au+Au and Cu+Cu are similar (for same  $\langle N_{\text{part}} \rangle$ )

# Collision Geometry



$$r = r_0 A^{1/3} \text{ fm}$$

$$r_{Au} = 7 \text{ fm}, r_{Cu} = 4.8 \text{ fm}$$

$$N_{nucleon}(z) = \frac{2z}{1 \text{ fm}}; N_{nucleon}(0) = \frac{2r_0 A^{1/3}}{1 \text{ fm}}$$

$$r^2 = \text{const} = z^2 + y^2$$

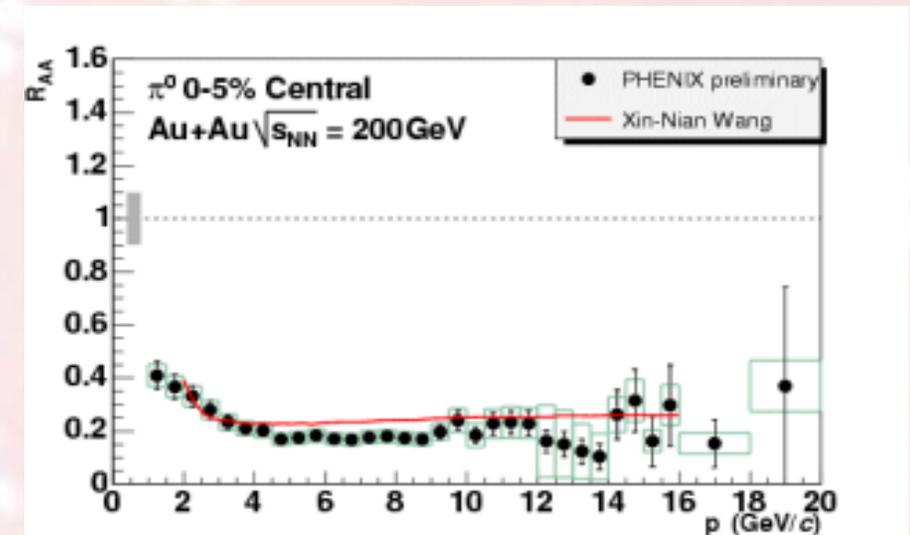
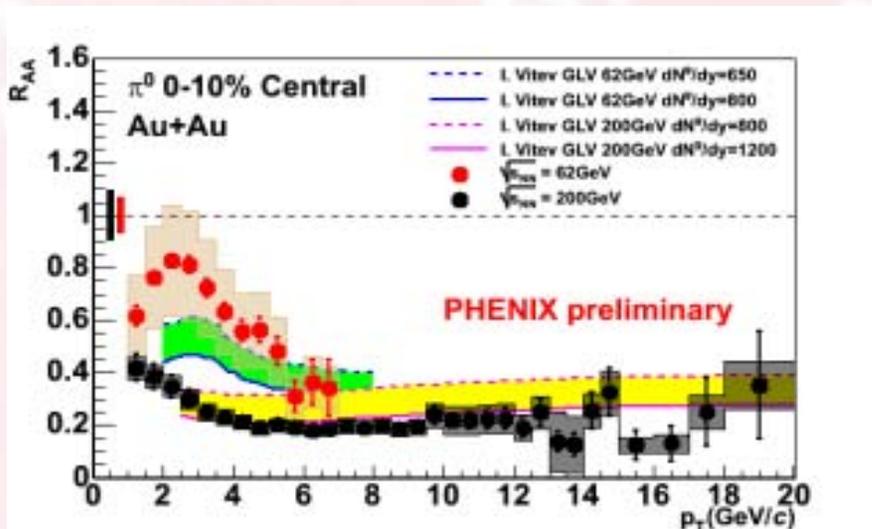
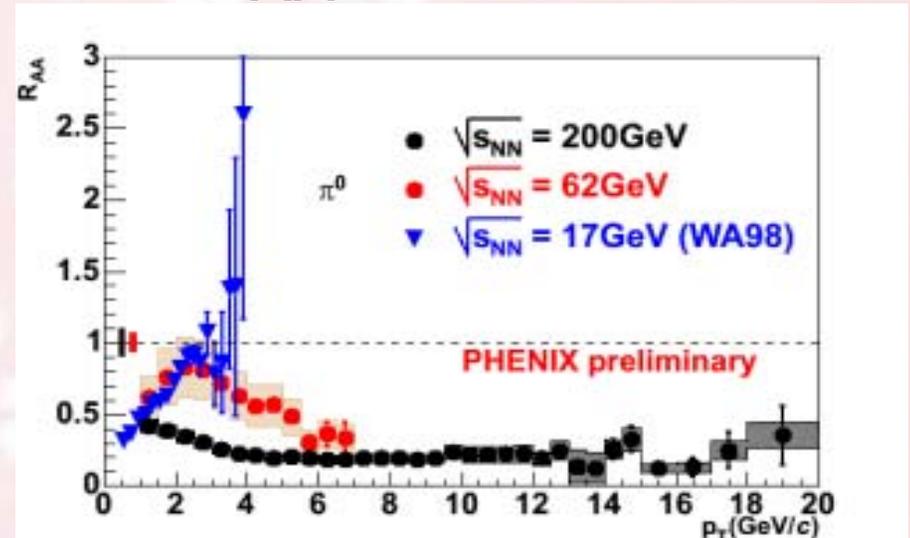
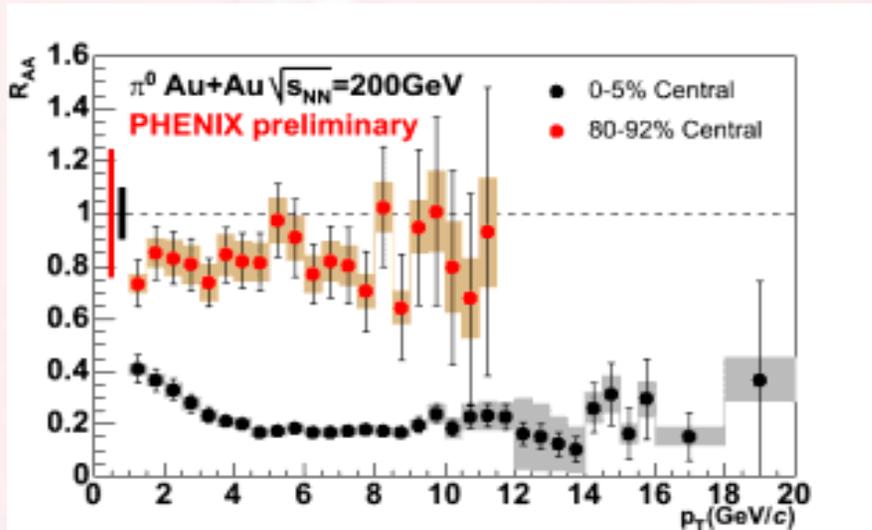
- One can calculate at what impact parameter  $b (= 2y)$  in Au+Au that one gets the same  $N_{nucleon}$  as a central Cu+Cu collision (where  $N_{nucleon}(0) \sim 10$ ):

$$y = (7^2 - z^2)^{1/2} \approx 5$$

$$b = 10 \text{ fm}$$

- For Au+Au,  $b=10 \text{ fm}$  corresponds to  $\sim 40\%$  centrality...

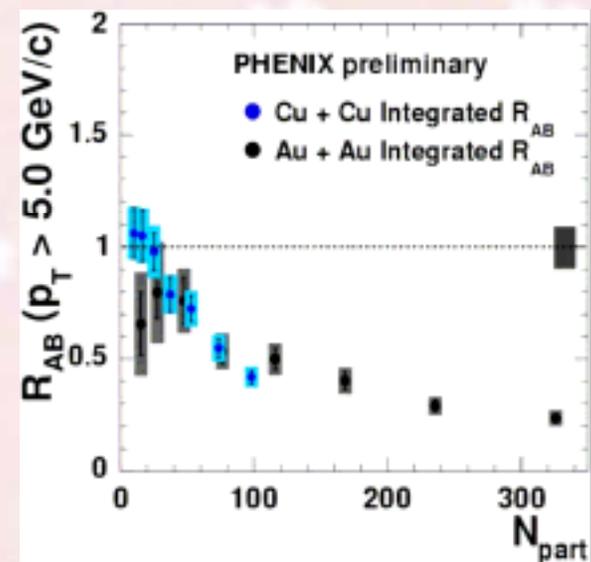
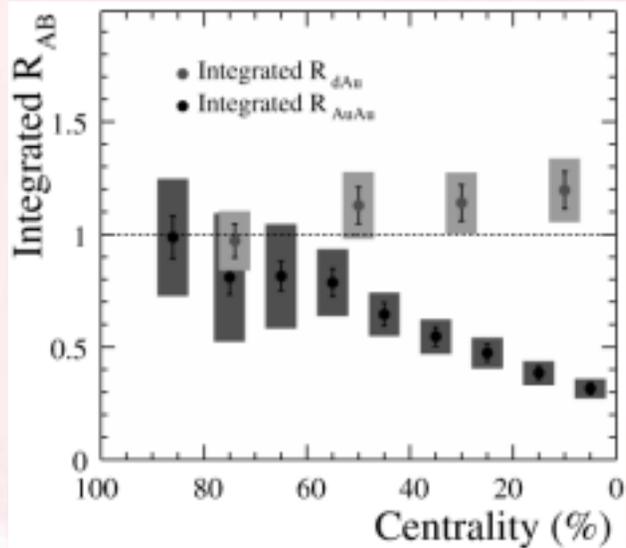
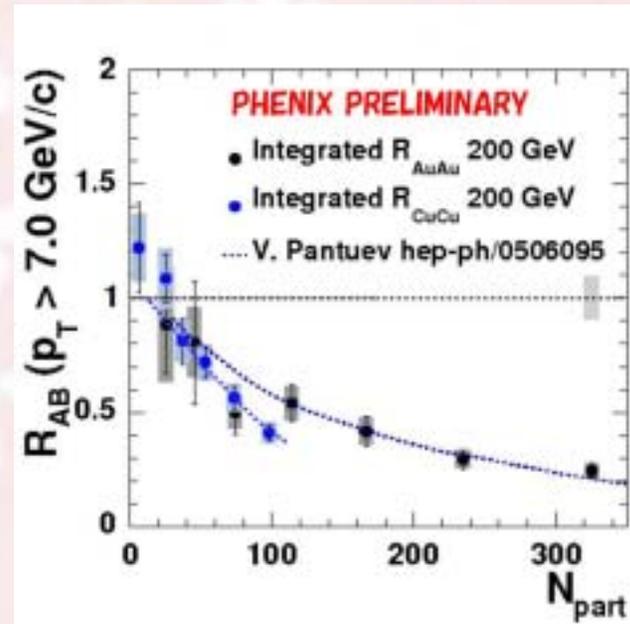
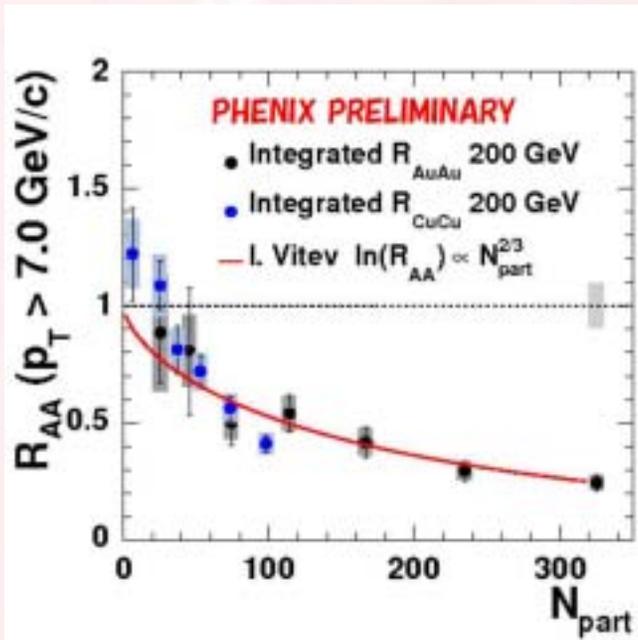
# Au+Au $\pi^0$ $R_{AA}$



Phys. Rev. Lett. 89, 252301, 2002  
 nucl-th/0404052

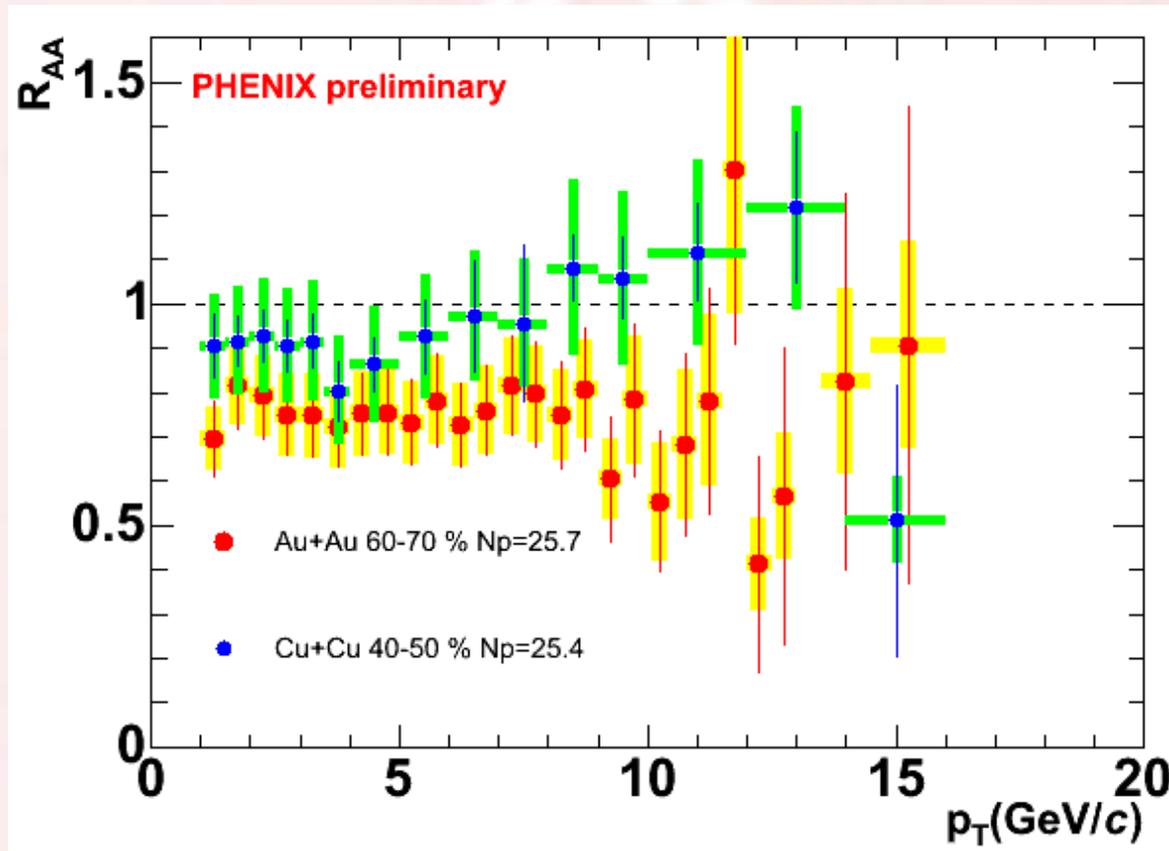
Phys.Lett.B595:165-170,2004

# Integrated $R_{AB}$ $\pi^0$ $\sqrt{s_{NN}} = 200\text{GeV}$

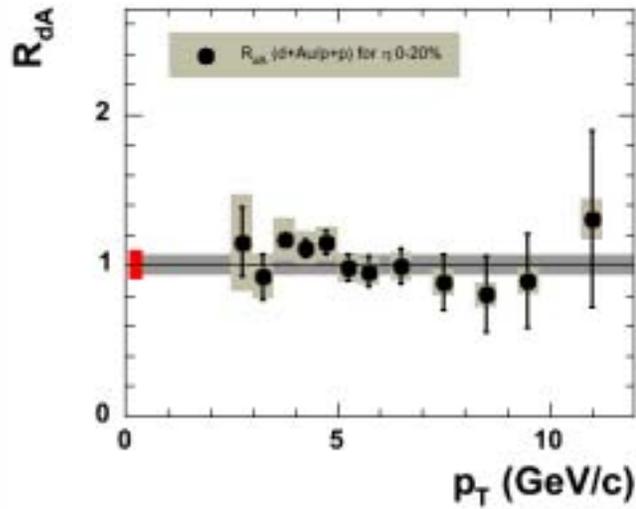


# Comparison of $\pi^0$ RAA in Cu+Cu collision to $\pi^0$ RAA in Au+Au collision as the function of Npart

Peripheral (Au + Au)    Mid central (Cu + Cu)



# $R_{dA}$ of $\eta$



$\eta$

